Cosmic Gamma-Ray Bursts

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IKI RAS, Moscow

MEPhI School, 31 May, 2006
GRB are running with hyperluminal speed since their discovery in 1973.

**Public debate:**
- 1995: Don Lamb – Halo (USA)
- 1995: Bogdan Paczynski - Cosmology
GRB from SN explosion:
Bisnovatyi-Kogan,
Imshennik, Nadyozhin,
Chehchetkin (1975)

X-rays (Beppo-SAX),
optical telescope, HST
REST ENERGY OF THE SUN IS

\[ 1.8 \cdot 10^{54} \text{ ergs} \]

[Star-Antistar annihilation ???]

Collimation is needed to decrease the energy!

The RESTRICTIONS to the model follow from

1. Energy conservation law,
   \[ W < Mc^2 \]

2. Stronger restrictions are from physical laws:
   the weakly interacting neutrino can be transformed into the radiation only with a rather low efficiency.
The GRB models may be classified by two levels.

I. Models of Radiation
   1. Fireball.
   2. Cannon ball (or gun bullet).
   3. Precessing jets.

II. The main restrictions are connected with the next (basic) level of GRB model, related to the Energy Source.

1. (NS+NS), (NS+BH) mergers.
   Ruffert, Yanka (1998,1999)
   Gamma radiation is produced here by $(\nu, \bar{\nu})$ annihilation,
   $\varepsilon \sim 10^{-2} - 10^{-3}$,
   $W_{\chi,\nu} \leq 10^{50}$ ergs.
2. Magnetorotational explosion. Suggested for supernova core-collapse explosion by Bisnovatyi-Kogan, (1970), Ardelyan, B.-K., Moiseenko (1994-2004). Numerical calculations gave the efficiency of a transformation of the rotational energy $E_{\text{rot}} \leq 5 \cdot 10^{52} \text{ ergs}$ into the kinetic energy of the ejection $\sim 10\%$. This is enough for an explanation of the supernova energy, but too low for cosmological GRB. Transformation of the $E_{\text{kin}}$ into $(X, \gamma)$ with efficiency $\varepsilon_{X,\gamma} \sim 10^{-2} - 10^{-3}$.
3. **Hypernova (very powerful supernova).**

   Paczynski (1998) – explosion of a helium star (see also Blinnikov and Postnov, 1998)

   Usov (1992) – new born pulsar, very rapid, with high magnetic field

   Cherepashchuk, Gershtein et al. (2002) W-R stars as GRB predecessors

   Woosley et al. (2001) collapse of very massive star, formation of a black hole with a massive disk

   (may be with magnetic field)

Now it is the most popular model. Traces of SNe are believed to be found in optical afterglows of several GRB.
4. Magnetized disk around rotating (Kerr) black hole (RBH)
   Van Putten (2001). Extraction of rotational energy of RBH when magnetic
   field is connecting the RBH with the surrounding accretion disk or accretion
   torus: Blandford—Znajek mechanism.

5. Vacuum explosion by strongly charged Black Hole
   Ruffini (2000). Problems with formation of such strongly charged black hole.

6. Shock behind the neutron star after SN explosion in companion

7. GRB from superconducting strings,
   Berezinsky at al., PR D (2001), 64, 043004

8. Transition from neutron star to quark star,
   Berezhiani et al. astro-ph/02-09-257
FIG. 1. Mass radius relation for pure strange quark matter stars (left) and hybrid stars (right); G0: $g = 0$ (no medium effect), ..., G4: $g = 4$ (maximum medium effect); H: pure hadronic star, QC: star has a quark core, MC: star has a mixed core.

FIG. 3. Mass-radius relation for a quark star with $\Lambda/\mu = 1.6$ and $\Lambda/\mu = 1$. The weak-coupling results for the same choice of renormalization scales are shown as dashed lines. $M_\odot = 1.989 \times 10^{30}$ kg is the mass of our sun.
Cosmological GRB model is based on

1. Statistics  2. Redshifts in optical afterglows

Statistics.
Deviations of the observed distribution of \( \log N - \log S \) from the uniform
distribution with slope is 3/2, and \( \langle V/V_{\text{max}} \rangle = 0.5 \), \( V \) is a volume, where
the source is visible, \( V_{\text{max}} \) is a maximum volume from which it could be visible.

Observational results
KONUS (1978-1979) \(~\) 150 GRB  \( \langle V/V_{\text{max}} \rangle = 0.45 \pm 0.03 \), Schmidt (1990).
BATSE (1991-2000) \(~\) 3000 GRB  \( \langle V/V_{\text{max}} \rangle = 0.33 \pm 0.01 \), Schmidt (1999)

These results contradict each other.

KONUS was in the interplanetary mission with small constant background.
BATSE was in the orbit around Earth, crossing radiation belts, background changed \(~\) 5 times.

Unknown selection effects ?
GRB positions on the sky in galactic coordinates
in KONUS experiment
log $N$ – log $S$ dependence for GRB in KONUS experiment (before account of selection effects).
After development $<V/V_{\text{max}}>=0.45 \pm 0.03$
The angular distribution of 1121 bursts in galactic coordinates. There is no statistically significant deviations from isotropy. (Experiment BATSE)
The log N-log P distribution for combined BATSE and PVO data. Strongest bursts give \(-3/2\) power law.
The curve \( \log N - \log \frac{C_{\text{max}}}{C_{\text{thr}}} \) in presence of stochastic errors, distributed according to normal law. The scattering in units of threshold value is: 0 for the curve 1 (straight line, -3/2 slope); 3 for curve 2; 10 for curve 3.
Fluence $F$ vs. redshift $Z$ for GRB with known $Z$:

**NO CORRELATION**
The magnitudes of the counterparts (upper limit - solid line, lower limit - dashed line) as a function of time after burst for GRB with total flux near the Earth $F_{\text{GRB}} = 10^{-4} \text{ erg/cm}^2$:

1a. for the case $E = 10^{52} \text{ erg}; n_0 = 10^5 \text{ cm}^{-3}$;

1b. for the case $E = 10^{51} \text{ erg}; n_0 = 10^5 \text{ cm}^{-3}$

(B.-K., Timokhin, 1997)
Temperature distribution in the part of non-uniform cloud with $N_{\text{max}}=10^{-5}$, (low-density cone) in the cone after GRB with isotropic energy output $10^{52}$ erg, Barkov (2004), PhD.

$$\theta = \pi / 10$$

Barkov, Bisnovatyi-Kogan: astro/ph 0410186
Collimation

In the “cannon-ball” model (Dar et al.) the bulk motion Lorentz factor is \( \Gamma \sim 10^2 - 10^3 \), leading to collimation factor \( \Omega \sim 10^{-4} - 10^{-6} \).

The restriction to the collimation angle follow from the analysis of the probability of appearance of the orphan optical afterglow, which probably have lower collimation. No orphan optical burst were detected, while it was expected to detect \(~0.2\) afterglows, if bursts are isotropic, so their absence suggests \( \Omega_{opt}/\Omega_\gamma << 100 \) (Rhoads, 2001; Levinson et al., 2002).

At radio wavelengths a limit on collimation angle is \( \theta_\gamma \geq 5^\circ \). Radio afterglows are expected to radiate isotropically, and the orphan limits on radio \( \Omega_{R}/\Omega_\gamma \) implies a limit on \( \Omega_\gamma \) itself (still uncertain).

Beeming should lead to correlation between luminosity and duration – Not visible, contradiction with cannon-ball model, and other models based on relativistic bulk motion.
Prompt Optical Emission.

**GRB990123**  about 100 s.  T(50%)=30 s.  T(90%)=63 s.

F(BATSE)=5.1 $10^{-4}$ erg/cm²

ASCA 2-10 keV,  55 h ,  $10^{-12}$ erg/cm²/s

OSSE  < 10MeV;  COMPTEL  0.2-30 MeV (46 s.)

Beppo-SAX - Localization

**Optics:**

ROTSE, Los Alamos,  t > 22.18 s after beginning of GRB

Unfiltered light

Jan 24, 40 min. KECK spectrum (optical)

Lines:  Mg II, Si II, Fe II, Zn II, C IV, Al II, Fe II …

**Redshift: z=1.61  Q(gamma)>2.3 $10^{54}$ erg**

L(opt) > $2$ $10^{16}$ Solar Luminosity = 8 $10^{49}$ erg/s

**Radio:**  VLA  8.46 GHz   about 260 microJansky;

Westerbork  4.88 GHz   < 130 microJansky;  Jan. 24.4,  15 GHz – NO FLUX

**GRB 021004** (15m, z=2.3)

**GRB 030329** (12.4m, z=0.168)

**GRB 030418** (16.9m)
Thin lines represent BATSE gamma-ray profile with 1024 ms resolution in different energy channels. The thick line represents the first few frames of ROTSE data. ROTSE began taking data 22 seconds after the initial trigger. This is the first instance of simultaneous optical and gamma-ray data from a gamma-ray burst, and also holds the record for the brightest ever optical burst.
GRB030329 in gamma-ray
Konus-Wind (UT) 11:37:29

- Fluence = $1.2 \times 10^{-4}$ erg/cm$^2$
- Duration = $\sim$50 s
- Peak Flux = $2.5 \times 10^{-5}$ erg/cm$^2$/s
- One of the most luminous bursts (from $\sim$4000)
GRB030329: optics first day

Object = 571 of 18022, Designation: ROTSE3 J104450.01+213117.7

ROTSE data
Rykoff, E. S. et al, GCN notice #1995
OT GRB030329
(A.S. Pozanenko, IKI, Moscow)
GRB030329: optics first day
OT 030329, First 5 days

AT-64, CrAO, Integral, 2003-03-29 - 2003-04-02

Magnitude

Hours after the burst of GRB030329
Variability in hours scale

CrAO

GRB 030329 R band

Magnitude

Hours after the burst of GRB 030329
Astro-ph/0309419, Price et al.
GRB030329: Optical light curve
(U)BVRI CrAO
## Linear polarization

**UT=** March, 29 18:31 – 21:07  (CrAO)

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<th>Err</th>
<th>PA</th>
<th>Err</th>
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<td>0.3178</td>
<td>V</td>
<td>0.41</td>
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<tr>
<td>* 0.3261</td>
<td>R</td>
<td>0.90</td>
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<tr>
<td>* 0.3222</td>
<td>I</td>
<td>0.92</td>
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<td>0</td>
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<td>58</td>
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</tbody>
</table>
Astro-ph/0309419, Price et al.
Astro-ph/0309419, Price et al.
GRB and Supernova explosions

GRB980425    \( z=0.0085 \) (40 Mpc)
GRB980326    \( z=1 \)
GRB011121    \( z=0.365 \)
GRB020405    \( z=0.695 \)

**GRB 060218/SN 2006aj**    \( z=0.033 \)

- Sokolov et al. (1998)
- Bloom, Kulkarni et al. (1999, 2002)

15-75 day: “red bump” in the optical afterglow:

Consistent with the underlying SN explosion
Optical and HST afterglow of GRB011112, Bloom et al. (2002)

![Light-curves of the afterglow and the intermediate-time red bump of GRB 011121](image)

**Fig. 2.** Light-curves of the afterglow and the intermediate-time red bump of GRB 011121. The triangles are our HST photometry in the F555W, F702W, F814W and F850LP filters (all corrected for the estimated contribution from the host galaxy), and the diamonds are ground-based measurements from the literature (Olsen et al. 2001; Stanek & Wyrzykowski 2001). The dashed line is our fit to the optical afterglow (see Paper II), the dotted line is the expected flux from the template SN at the redshift of GRB 011121, with foreground extinction applied and dimmed by 55% to approximately fit the data, and the solid line is the sum of the afterglow and SN components. Corrections for color effects between the ground-based filters and the HST filters were taken to be negligible for the purpose of this exercise.

SNe themselves and the explosion mechanism. The three main physical parameters of a Type Ib/Ic SN are the total explosive energy, the mass of the ejecta, and the amount of Nickel synthesized by the explosion ($M_{\text{Ni}}$). The peak luminosity and time to peak are roughly determined by the explosion energy and the mass of the ejecta, while the amount of synthesized Nickel is key to the type Ib/Ic designation. There has been significant discussion in the literature as to the degree which the central engine in GRBs will affect the overall explosion of the star (Woosley 1993; Khokhlov et al. 1999; MacFadyen & Woosley 1999; Höflich et al. 1999; MacFadyen et al. 2001). These models currently have focused primarily on...
Fig. 3.— Light curves of the optical afterglow of GRB 020405, assuming zero afterglow flux in the final HST measurements. Open points are used for ground-based measurements, filled points for HST measurements. The dashed line is a single power-law decay model (isotropic emission). The solid line is a broken power-law decay model (jet). Both models incorporate a power-law spectrum and are fit to data taken before 10 days. We have plotted the light curve of SN 1998bw shifted to $z = 0.690$ and dimmed by 0.5 mag over the HST data for a rough comparison. The flux in the F814W filter is an underestimate; see the text for an explanation. Reddening the SN 1998bw light-curve to account for host extinction may produce a better match, but the extinction along the line-of-sight cannot be precisely determined from the current data.
Stanek et al., astro-ph/0304173
Observations of SN 2003dh/GRB 030329 are an average of both May 8 and 9 spectra, template spectrum of an Sc-type galaxy has been subtracted and those of other hypernovae.

Kawabata et al., astro-ph/0306155
Spectral evolution of the combined optical flux density, of the afterglow of GRB030329, the associated SN2003dh, and its host galaxy.
All spectra are plotted as a function of restframe wavelength and labeled with the time since the GRB, corrected for the cosmological time dilation $(1+z)$.

Hjorth et al.,
astro-ph/0306347
The MPFS spectra (in restframe wavelengths) smoothed by a gaussian with FWHM equal to MPFS spectral resolution (12\AA). The smoothed spectra of GRB~030329 OT were shifted up the scale of $f_\lambda$ relative to the last (12.4 h) spectrum by $+0.2\,\text{E}\!-\!15$ for 11.5 h, $+0.6\,\text{E}\!-\!15$ for 11.3 h, and $+1.2\,\text{E}\!-\!15$ for 10.8 h spectra, respectively.

astro-ph/0312359, Sokolov et al.
Calculated light curves for envelope mass 0.89 Solar. The bolometric light curve of SN 1993J is shown by the filled circles,
The GRB 060218/SN 2006aj event in the context of other Gamma-Ray Burst Supernovae

We present VLT FORS multi-color photometry of SN 2006aj, the supernova associated with GRB060218 at a redshift of $z=0.033$, the second closest GRB-SN observed to date.

**Fig. 1.** The light curves of SN 2006aj based on our $BVRI$ data after correcting for extinction and host flux contribution, fitted by not considering data before 8.8 days in the fit. The residuals $\Delta m$ represent observed values minus the fit.

**Fig. 2.** The light curves of SN 2006aj fitted by including an additional early component which decays according to a power law. Solid lines mark the fit, the dashed lines are the power-law component and the dotted lines are the SN component. The time scale is logarithmic to show in detail the earlier data.
Swift is a multi-wavelength observatory dedicated to the study of gamma-ray burst (GRB) science. Its three instruments will work together to observe GRBs and afterglows in the gamma-ray, X-ray, optical, and ultraviolet wavebands. Swift, part of NASA’s medium explorer (MIDEX) program, was developed by an international collaboration and was launched into a low-Earth orbit on a Delta 7320 rocket on November 17, 2004. During its nominal 2-year mission, Swift is expected to observe more than 200 bursts, which will represent the most comprehensive study of GRB afterglows to date.

Launched 20 November 2004
### Mission Details

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
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<tr>
<td>Orbit</td>
<td>LEO 600 km circular</td>
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<td>Orbital Life</td>
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<tr>
<td>Inclination</td>
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<td>Launch Date</td>
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<tr>
<td>Prime Mission Duration</td>
<td>2 years</td>
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<td>Launcher</td>
<td>Delta II (7320)</td>
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<tr>
<td>Spacecraft Partner</td>
<td>Spectrum Astro</td>
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<tr>
<td>Peak Slew Rate</td>
<td>50 degrees in &lt; 75 sec</td>
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<tr>
<td>Operations and Pointing</td>
<td>Autonomous</td>
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<tr>
<td>Uplink/Downlink</td>
<td>Dual Path</td>
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<tr>
<td></td>
<td>• 2 kbps GRB alert downlink and uplink real-time using TDRSS DAS link</td>
</tr>
<tr>
<td></td>
<td>• 2.25 Mbps data rate for store and dump using Malindi-ASI seven orbits per day</td>
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### Burst Alert Telescope

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<th>Feature</th>
<th>Details</th>
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<td>Aperture</td>
<td>Coded Mask</td>
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<tr>
<td>Detecting Area</td>
<td>5200 cm²</td>
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<tr>
<td>Detector</td>
<td>CdZnTe</td>
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<tr>
<td>Detector Operation</td>
<td>Photon Counting</td>
</tr>
<tr>
<td>Field of View</td>
<td>2.0 sr (partially coded)</td>
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<tr>
<td>Detection Elements</td>
<td>256 modules of 128 elements</td>
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<tr>
<td>Detector Size</td>
<td>4mm x 4mm x 2mm</td>
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<tr>
<td>Telescope PSF</td>
<td>17 arcminutes</td>
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<tr>
<td>Location Accuracy</td>
<td>1 - 4 arcminutes</td>
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<td>Energy Range</td>
<td>15 - 150 keV</td>
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<td>Burst Detection Rate</td>
<td>&gt;100 bursts/year</td>
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**X-Ray Telescope**

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<th>Parameter</th>
<th>Description</th>
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<td>Telescope</td>
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<tr>
<td>Detector</td>
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<tr>
<td>Effective Area</td>
<td>135 cm² @ 1.5 keV</td>
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<td>Detector Operation</td>
<td>Photon Counting, Integrated Imaging, &amp; Rapid Timing</td>
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<td>Field of View</td>
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<td>Detection Element</td>
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<td>2.36 arcsec/pixel</td>
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<td>Telescope PSF</td>
<td>18 arcsec HPD @ 1.5 keV</td>
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<td>Location Accuracy</td>
<td>3 - 5 arcseconds</td>
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<tr>
<td>Energy Range</td>
<td>0.2 - 10 keV</td>
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<tr>
<td>Sensitivity</td>
<td>$2 \times 10^{-14}$ ergs cm² s⁻¹ in 10⁴ sec</td>
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**UltraViolet/Optical Telescope**

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<td>Detector</td>
<td>Interfaced CCD</td>
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<td>Photon Counting</td>
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<td>Field of View</td>
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<td>Colors</td>
<td>6</td>
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<tr>
<td>Spectral Resolution [Grisms]</td>
<td>$\lambda / \Delta \lambda \sim 200 @ 400$ nm</td>
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<tr>
<td>Sensitivity</td>
<td>B = 24 in white light in 1000 sec</td>
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<tr>
<td>Pixel Scale</td>
<td>0.48 arcseconds</td>
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<td>Bright Limit</td>
<td>$m_v = 7$ mag</td>
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GRB 050505: A high redshift burst detected by *Swift*

We report the discovery and subsequent multi-wavelength afterglow behaviour of the high redshift ($z = 4.27$) Gamma Ray Burst GRB 050505. This burst is the third most distant burst, measured by spectroscopic redshift, discovered after GRB 000131 ($z = 4.50$) and GRB 050904 ($z = 6.29$).
Discovery and identification of the very high redshift afterglow of GRB 050904

At 01:51:44 UT on September 4, 2005, Swift's Burst Alert Telescope (BAT) detected GRB 050904 and 81 seconds later a 4 arcmin-radius localization was distributed to observers on the ground. Swift's X-Ray Telescope (XRT) automatically slewed to the BAT localization and 76 minutes after the burst a 6 arcsec-radius XRT localization was distributed. We began remote observations with the 4.1-m Southern Observatory for Astrophysical Research (SOAR) telescope atop Cerro Pachon in Chile beginning 3.0 hours after the burst. Using the Ohio State InfraRed Imager/Spectrometer (OSIRIS) in imaging mode, we discovered a relatively bright (J \( \approx \) 17.4 mag) and fading near-infrared (NIR) source within the XRT localization.

Our photometric redshift was later confirmed by two other groups: a photometric redshift that was obtained with one of the 8.2-m Very Large Telescopes and a spectroscopic redshift of 6.29 \( \pm \) 0.01 that was obtained with the 8.2-m Subaru telescope.
High energy afterglow (30-10000 MeV)

EGRET: 5 afterlows, up to 1.5 hours
1/3 of all GRB should be observable in hard gamma
Spectral slope: $E^{-2.0} -- E^{-3.7}$

Crab (pulsar, nebula) (-1.78) -- (-2.75)

Hard radiation from vibrating neutron star,
Like from rotating pulsar.
The burst of 17 February 1994, observed to emit GeV photons up to 1.5 hours after the initial outburst, as observed by EGRET experiment. The composite figure includes data from EGRET, Ulysses and BATSE experiment.
Table 2: EGRET Energetic Gamma-Ray Burst Observations, from [59]

<table>
<thead>
<tr>
<th>Burst ID</th>
<th>Max. Energy (GeV)</th>
<th>Duration Emission</th>
<th>Spectral Function</th>
<th>Delayed Emission</th>
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<td>10</td>
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<td>GRB930131</td>
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<td>100 s</td>
<td>$E^{-2.0}$</td>
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<td>GRB940217</td>
<td>18</td>
<td>1.5 h</td>
<td>$E^{-2.6}$</td>
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<td>GRB940301</td>
<td>0.16</td>
<td>30 s</td>
<td>$E^{-2.5}$</td>
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About 30% of all GRB emit in hard gamma rays

AGILE
GLAST

CYGAM (?)

V.V.Akimov,
G.S.Bisnovatyi-Kogan,
N.G.Leikov

CYlindrical GAmma-ray Monitor CYGAM
NEW CONCEPT OF THE HIGH-ENERGY GAMMA-RAY TELESCOPE

Moscow 2003
Traditional scheme (EGRET)  
Scheme of CYGAM.  
Drift chambers
Comparative characteristics of GYGAM and EGRET

<table>
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<th>Characteristic</th>
<th>EGRET</th>
<th>CYGAM</th>
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<tr>
<td>Angle Resolution</td>
<td>2.6° (100 MeV)</td>
<td>0.4° (1000 MeV)</td>
</tr>
<tr>
<td>1.0° (1000 MeV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Resolution, %</td>
<td>20</td>
<td>–</td>
</tr>
<tr>
<td>Dimensions, m</td>
<td>Ø 1.65 x 2.25</td>
<td>Ø 2 x 2</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>1830</td>
<td>~1000</td>
</tr>
</tbody>
</table>
Hard X-ray lines:

30—60 keV (absorption)
cyclotron (?), heavy elements (?)

KONUS: 1/3 of all GRB have lines

BATSE: 13 from 117 (12%)
(worse spectral resolution)

Absorption in the expanding cloud (1989) -- in local GRB model
in relativistically moving gas cloud (1999)
Γ = 25-100 -- in cosmological GRB model
Spectral evolution of 1 November 1979 burst. (1-2) -spectrum obtained in the first 8 s with absorption line at 65 keV and broad emission feature at 350-650 keV; (4) -spectrum measured in the 4-th 4 s interval; (6-8) -spectrum summed over 6-th, 7-th and 8-th intervals (Mazets et al., 1982)
**Apsorption line formation in the expanding cloud** (B.-K., Illarionov, 1989)

\[ t(a) = t(1)/2, \quad Y = 1/300, \quad \tau(a) = \tau(I=43 \text{ keV}) = \tau(T) + \tau(Y) = 130 + 9 \]

\[ t(b) = t(1), \quad M(20) = 1, \quad \tau(b) = \tau(I=43 \text{ keV}) = \tau(T) + \tau(Y) = 1 + 2.3 \]

\[ t(c) = 2t(1), \quad L(38) = 1, \quad \tau(c) = \tau(I=43 \text{ keV}) = \tau(T) + \tau(Y) = 0.015 + 0.6 \]
X-ray spectrum 22-83 s. after BATSE trigger. Fitting without line.
X ray-spectrum 22-83 s. after BATSE trigger

Fitting with narrow line at 45 keV, improve $\chi^2$ by 23.1.
X-ray spectrum 22-83 s. after BATSE trigger.
Fitting with narrow line at 45 keV, worse $\chi^2$ by 9.7.

13 from 117 GRB from BATSE have statistically significant lines (GRB941017,...)
GRB 021206: 80% polarization in Gamma Rays around 1 MeV

1. Polarization of the prompt $\gamma$-ray emission from the $\gamma$-ray burst of 6 December 2002

Wayne Coburn* & Steven E. Boggs*;†


2. Re-Analysis of Polarization in the $\gamma$-ray flux of GRB 021206

astro-ph/0310385 Robert E. Rutledge and Derek B. Fox¹

3. Statistical uncertainty in the re-analysis of polarization

astro-ph/0310385 in GRB021206 Boggs, Corburn
1.

Figure 1: *RHESSI* light curves (in total measured counts) in three energy bins for GRB21206. The IPN localized this GRB to 18° off solar, which precluded optical afterglow searches; however, the brightness, duration, and proximity to the *RHESSI* rotation axis made it an ideal candidate to search for polarization. The shaded region shows our 5s integration time for the polarization analysis.

Figure 2: The azimuthal scatter distribution for the *RHESSI* data, corrected for spacecraft rotation. Counts were binned in 15° angular bins between 0°-180°, and plotted here twice for clarity. The top plot shows the raw measured distribution (crosses), as well as the simulated distribution for an unpolarized source (diamonds) as modelled with a Monte Carlo code, given the time-dependent incident flux. The bottom plot shows the *RHESSI* data with the simulated distribution subtracted. This residual is inconsistent with an unpolarized source (dashed line) at a confidence level $> 5.7 \sigma$. The solid line is the best-fit modulation curve, corresponding to a linear polarization of $(80 \pm 20)\%$. 

$R(\theta_n)$. However, $R$ is observationally consistent with being constant in $\theta$; thus, we find no evidence of polarization.
THE MOST PROBABLE CAUSE FOR THE HIGH GAMMA-RAY POLARIZATION IN GRB 021206

Jonathan Granot

astro-ph/0306322

The exciting detection of a very high degree of linear polarization, \( P = 80\% \pm 20\% \), in the prompt \( \gamma \)-ray emission of the recent GRB 021206, provides strong evidence that synchrotron emission is the dominant radiation produce \( P \gtrsim 50\% \) with an ordered field. More specifically, we obtain \( P \sim 43 - 61\% \) for an ordered transverse magnetic field, \( B_{\text{ord}} \), whereas a shock-produced field that is random but fully within the plane of the shock, \( B_{\perp} \), can produce up to \( P \lesssim 38 - 54\% \) for a single pulse in the GRB light curve, but the integrated emission over many pulses (as measured in GRB 021206) is expected to be a factor of \( \sim 2 \) lower. A magnetic field normal to the shock front, \( B_{\parallel} \), can produce \( P \sim 35 - 62\% \) for the emission integrated over many pulses. However, polarization measurements from GRB afterglows suggest a more isotropic configuration for the shock-produced field that should reduce \( P \) by a factor \( \sim 2 - 3 \). Therefore, an ordered magnetic field, \( B_{\text{ord}} \), that originates at the source, can produce the observed polarization most naturally, while \( B_{\parallel} \) is less likely, and \( B_{\perp} \) is the least likely of the above.

Compton drag as a mechanism for very high linear polarization in Gamma-Ray Bursts

astro-ph/0309038

Davide Lazzati\(^1\), Elena Rossi\(^1\), Gabriele Ghisellini\(^2\) & Martin J. Rees\(^1\)

that, under certain geometrical conditions, an even higher level of linear polarization is expected if the photons are produced by bulk inverse Compton scattering. We discuss

In the previous section we considered the polarization arising from the interaction of a single electron with an isotropic photon field. We here consider a jet fireball of opening angle \( \theta_j \), radially expanding at relativistic speed, observed from a viewing angle \( \theta_o \).
Gamma-Ray Burst Polarization: Limits from RHESSI Measurements
C. Wigger, W. Hajdas, K. Arzner, M. Gedel, and A. Zehnder

ABSTRACT
Using the RHESSI satellite as a Compton polarimeter, a recent study claimed that the prompt emission of GRB 021206 was almost fully linearly polarized. This was challenged by a subsequent reanalysis. We present a novel approach, applying our method to the same data.

For GRB 021206, we formally find a linear polarization degree of GRB \(= 41\%\), concluding that the data quality is insufficient to constrain the polarization degree in this case. We further applied our analysis to GRB 030519B and again found a null result.
**Figure 2.** Polarization as a function of the observing angle $\theta_o$ in units of $1/\Gamma$ for a uniform jet with sharp edges. Different line styles show the polarization for jets with different opening angles. The lines are thicker in the region where the efficiency is larger than 2.5%.  

**Figure 4.** Same as Fig. 2 but for a Gaussian jet (see text). Since in this jet the Lorentz factor is not uniform, the observing angle $\theta_o$ is shown, in the x axis, in units of $1/\Gamma_0$, the Lorentz factor along the jet axis.
The first XMM-Newton observation of **GRB031203** began at 2003-12-04, UT04:09:29 and lasted for 58211 seconds (GCN2462). The GRB was originally detected by the IBIS instrument on Integral at 2003-12-03, UT 22:01:28 (GCN2459).

Analysis of the first XMM-Newton observation reveals a diffuse X-ray halo centered around the GRB afterglow location. This halo is seen in all three cameras of the EPIC instrument and is not due to scattered optical or X-ray light within the instrument. The halo has the form of a virtually complete ring which increases in radius through the observation, indicative of the expected behaviour of a "light-echo" as X-rays are scattered off dust at a distance of ~700 pc from the observer.

**GRB031203 is in the direction (Galactic) l = 255.74, b = -4.80 degrees, a line of sight which includes the Gum Nebula among other nebulae and infrared sources. The derived distance to the scattering medium is consistent with an origin in our Galaxy.**

The X-ray spectrum of GRB031203 can be well represented by a powerlaw with Photon index ~ 1.7. The scattered X-ray light has, as expected, a softer spectrum with Photon index ~ 3. Further analysis is underway.
X-Ray Rings Expand from a Gamma Ray Burst Credit: S. Vaughan, R. Willingale (U. Leicester) et al.,

XMM, ESA Explanation: Why do x-ray rings appear to emanate from a gamma-ray burst? The surprising answer has little to do with the explosion itself but rather with light reflected off sheets of dust-laden gas in our own Milky Way Galaxy. GRB 031203 was a tremendous explosion -- a gamma-ray burst that occurred far across the universe with radiation just arriving in our Solar System last December 3. Since GRBs can also emit copious amounts of x-rays, a bright flash of x-rays likely arrived simultaneously with the gamma-radiation. In this case, the x-rays also bounced off two slabs of cosmic dust nearly 3500 light-years distant and created the unusual reflections. The longer path from the GRB, to the dust slab, to the XMM-Newton telescope caused the x-ray light echoes to arrive well after the GRB.
The halo appeared as concentric ring-like structures centered on the GRB location. The radii of these structures increased with time as $t^{1/2}$, consistent with small-angle X-ray scattering caused by a large column of dust along the line of sight to a cosmologically distant GRB. The rings are due to dust concentrated in two distinct slabs in the Galaxy located at distances of 880 and 1390 pc, consistent with known Galactic features. The halo brightness implies an initial soft X-ray pulse consistent with the observed GRB.

**Explosion in the dust:**

$$x = \sqrt{2ct \left( \frac{1}{d_1} + \frac{1}{d_2} \right)^{-1}}$$
The presence of decaying, soft X-ray lines was not predicted by GRB models and illustrates the potential of XMM-Newton for such work. Equally intriguing is the lack of iron emission in GRB011211. The best-fit model for the emission is, surprisingly, an optically-thin thermal plasma. Although unlikely to be fully physically realistic, this model allows for an estimate of the abundances and ejected mass. For the light elements an abundance some 10 x Solar is required but <1.4 x Solar for iron.

Again, the soft X-ray line spectrum in GRB030227 can be well fitted by a thermal plasma, giving a minimum abundance of 24x Solar for the light elements compared to <1.6 and <18 for Fe and Ni respectively.

The observations of X-ray afterglows have revealed a wealth of spectral detail only just beginning to be understood. XMM-Newton has already made a major contribution to our understanding of GRBs, providing data that challenge and in some cases contradict so-called ``standard models''.

XMM-Newton GRB observations (astro-ph/0312602)

GRB011211: z(opt)=2.140, z(X)=1.86
• GRB040223 was discovered by INTEGRAL on February 23, 2004 at 13:28 UTC in the field of view of the IBIS telescope (GCN2525).

• The GRB was approved by the XMM-Newton Project Scientist for a ToO observation during the ongoing revolution 771.

• The EPIC exposure was started on 2004-02-23 at 18:21 UT, less than 5 hrs after the occurrence of the burst, and lasted for a total of 42 ksec. This has been the fastest XMM-Newton ToO response to date. The pointing coordinates were RA=16h 39m 34.0s, Dec=-41deg 55' 46", as reported in the GCN/INTEGRAL NOTICE.

• Quick-Look-Analysis of the first 7 ksec of the XMM-Newton observation of the GRB040223 field showed the presence of a bright source in the EPIC-pn and MOS cameras within the INTEGRAL error circle, XMMU J163929.9-415601 (Breitfellner, Munuera and Martos, GCN2530) at a position of R.A. (J2000) = 16h 39m 29.9s, Decl. (J2000)= -41deg 56' 1.4", with a positional accuracy better than 6 arcsec, F ~ 10^(-13) erg/s/cm^2.
The time history of the giant burst from the soft gamma repeater SGR 1627-41. on June 18, 6153 s UT corrected for dead time. Photon energy E > 15 keV. The rise time is about 100 ms (Mazets, 1999a).

Giant Bursts in Soft Gamma Repeaters inside the Galaxy: all 4 GRB had them during 30 years

The strongest one was 27 Dec 2004 in SGR 1806-20
The Konus-Wind and Helicon-Coronas-F detection of the giant 
\(\gamma\)-ray flare from the soft \(\gamma\)-ray repeater SGR 1806-20

E. P. Mazets\(^1\), T. L. Cline\(^2\), R. L. Aptekar\(^1\), D. D. Frederiks\(^1\), S. V. Golenetskii\(^1\), V. N. Il’inskii\(^1\), & V. D. Pal’shin\(^1\)

The giant outburst from SGR 1806-20 was observed on 2004 December 27 by many spacecraft (ref. 1,2,3,4,5,6). This extremely rare event exhibits a striking similarity to the two giant outbursts thus far observed, on 1979 March 5 from SGR 0526-66 (ref. 7) and 1998 August 27 from SGR 1900+14 (ref. 8,9,10). All the three outbursts start with a short giant radiation pulse followed by a weaker tail. The tail pulsates with the period of neutron star rotation of \(\sim 5\)–8 s, to decay finally in a few minutes. The enormous intensity of the initial pulse proved to be far above the saturation level of the gamma-ray detectors, with the result that the most valuable data on the time structure and energy spectrum of the pulse is lost. At the time of the December 27 outburst, a Russian spacecraft Coronas-F with a \(\gamma\)-ray spectrometer aboard was occulted by the Earth and could not see the outburst. It succeed, however, in observing a weak reflected signal due to the \(\gamma\)-rays Compton scattered by the Moon (ref. 11). This has been the first observation of a cosmic gamma-ray flare reflected from a celestial body. Here we report, that the detection of a weakened back-scattered initial pulse combined with direct observations by the Konus \(\gamma\)-ray spectrometer on the Wind spacecraft permitted us to reliably reconstruct the intensity, time history, and energy spectra of the outburst.
strong anticorrelation. As a result, the estimates of the total energy in the pulse vary rather weakly. At a confidence level of 90% the fluence and the peak flux of the initial pulse in the 20 keV–10 MeV energy band are $0.61^{+0.35}_{-0.17}$ erg cm$^{-2}$ and $9.2^{+5.6}_{-3.1}$ erg cm$^{-2}$ s$^{-1}$. 
\[ P = 7.57 \pm 0.07 \text{ s.} \]
The history of the outburst from SRG 1806-20 (RXTE/PCA 2-60 keV). The top panel (a) shows a bright burst preceded by a long, complex precursor. The bottom panel (b) shows the precursor intervals used in the spectral analysis (Ibrahim et al., 2002).
SGR 1806-20:

spectrum and best-fit continuum model for the second precursor interval with 4 absorption lines (RXTE/PCA 2-30 keV), Ibrahim et al. (2002)
First evidence of a cyclotron feature in an anomalous X-ray pulsar

A proton RCF feature at 8.1 keV

would correspond to surface field of $1.6 \times 10^{15}$ G

We find that, for the higher magnetic field models ($B > B_Q$), vacuum polarization suppresses both the proton cyclotron line and spectral lines due to the bound species. As a result, the thermal spectra are almost featureless and blackbody-like.

$$B_Q = \frac{m_e^2 c^3}{e \hbar} = 4.414 \times 10^{13} \text{ G}$$
Conclusions

1. There is no fully consistent GRB model: neither radiation, nor explosion.

2. It is not excluded, that short GRB have nearby galactic origin.

3. Giant bursts in soft gamma repeaters (SGR) may be connected with short GRB.

4. Critical experiment is needed.
   Spectrum of the prompt optical afterglow. Hard gamma-ray afterglow.
   Search for orphaned optical afterglows: optical all sky monitor:

5. Cosmological GRB:
   Collapse of massive rotating star. Formation of Kerr black hole surrounded by massive magnetized disk. Rapid accretion leading to GRB.

Exotic models.